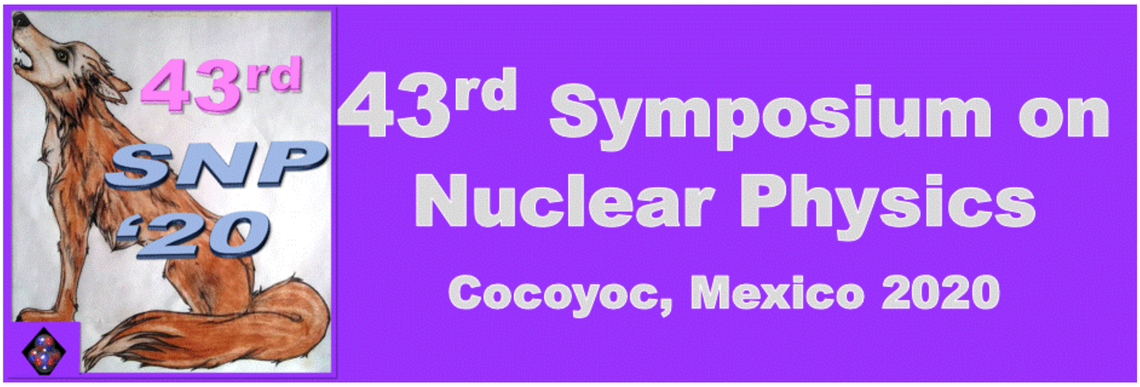

XLIII SYMPOSIUM ON NUCLEAR PHYSICS

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Book of Abstracts

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Luis Acosta (Instituto de Física, UNAM, México)
Elí Aguilera (Inst. Nac. de Investigaciones Nucleares, México)
Arturo Amor-Quiroz (Institut Polytechnique de Paris, France)
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TALKS

The new Mexican devices for nuclear studies and applications

L. Acosta[1], E. Chávez[1], L. Barrón-Palos[1], E. Andrade[1], D.J. Marín-Lámbarri[1], J. Miranda[1], M.E. Ortiz[1], F. Favela[2], C. Solís[1], C. Méndez-García[1,3], S. Padilla[1], A. Huerta[1] and M.A. Martínez-Carrillo[4]

1 Instituto de Física, UNAM, México
2 Instituto de Ciencias Nucleares, UNAM, México
3 Cátedras CONACyT, UNAM, México
4 Facultad de Ciencias, UNAM, México

Abstract

In the last 5 years, the Laboratorio Nacional de Espectrometría de Masas con Aceleradores (LEMA) at IFUNAM, México, have reached and important consolidation, due to the commissioning of the AMS technique for the study of ^{26}Al and ^{10}Be, the inclusion of a new beam line and the construction of a modern detection array. This new possibilities along with the previously consolidated radiocarbon measurements, a Jet Gas-target device and ancillary accelerators, compose a powerful Mexican facility for nuclear studies and applications. IBA techniques like RBS, NRA and PIXE have been commissioned at the new beam-line which has as well used for targets irradiation and nuclear reactions measurements. The present work is addressed to show recent results related to all this new devices and techniques, including some perspectives for further studies.

Angular zone of influence for fusion and direct reactions on elastic scattering of ^{6}Li + ^{64}Zn

E.F. Aguilera[1] **and F. Torabi**[1]
1 Instituto Nacional de Investigaciones Nucleares, México

Abstract

Recently, a systematic study of fusion and elastic scattering data was performed for the ^{6}Li + (^{58}Ni, ^{59}Co, ^{60}Ni, ^{64}Zn) systems. Appropriate polarization potentials satisfying the dispersion relation were extracted, which can be associated to fusion and direct reaction couplings, respectively. By examining the relative strengths of the corresponding absorptive parts, a semiclassical analysis can be carried out which gives an indication about the angular range where direct (fusion) reactions are more important in determining the elastic scattering angular distributions. The results of such an analysis are presented for the case of the ^{6}Li + ^{64}Zn system.

Expression for the angular momentum decomposition in the scalar diquark model

A. Amor-Quiroz[1]
1 Institut Polytechnique de Paris, France

Abstract

One of the challenges of both nuclear and hadronic physics is to fully understand the structure of nucleons and nuclei through the measurements of its structure functions. In particular, possible future experiments at the EIC are aimed to understand the origin of the spin of the proton. This requires a proper decomposition of the nucleons total angular momentum into an orbital motion and intrinsic spin. The most common decompositions of angular momentum are the Jaffe-Manohar (canonical) and Ji (kinetic) decompositions, which differ by the so-called "potential angular momentum" and that depend on how the contributions are attributed to quarks and gluons. Even if some lattice calculations has shown that difference between the decompositions is non-zero, we justify a non-vanishing potential angular momentum using perturbation theory within a simple scalar diquark model at two-loop level, and motivate the interpretation of such a difference as originating from the torque exerted by initial or final state interactions on the struck quark.

Towards the measurement of TRIV in the interaction of polarized low-energy neutrons and polarized nuclei

L. Barrón-Palos[1] **(for the NOPTREX collaboration)**
1 Instituto de Física, UNAM, México

Abstract

In this talk I will present the motivation of the NOPTREX collaboration to pursue studies of the possible TRIV in resonances of compound nuclei accesible with epithermal neutrons. The first of these studies, which aim to improve the precision on the PV effects in previously studied nuclei as well as measurements in new targets that could exhibit such PV effects will also be described.

Photocouplings of hidden-charm pentaquarks

R. Bijker[1] **and E. Ortiz-Pacheco**[1]

1 Instituto de Ciencias Nucleares, UNAM, Mxico

Abstract

We analyze the photocouplings of hidden-charm pentaquark configurations [1] in the framework of the deformed quark model in which we distinguish between the masses of the light quarks (u, d, s) and the heavy quarks [2]. The photocouplings are relevant to photoproduction experiments at JLab to try to excite hidden-charm pentaquarks with an electromagnetic probe.

[1] E. Ortiz-Pacheco, R. Bijker and C. Fernández-Ramírez, J. Phys. G 46, 065104 (2019)

[2] E. Ortiz-Pacheco and R. Bijker, in progress

Nuclear Astrophysics in underground laboratories: the LUNA experiment

A. Caciolli[1] **(for the LUNA collaboration)**

1 Università degli Studi di Padova and INFN Sezione di Padova, Padova, Italy

Abstract

One of the main ingredients of nuclear astrophysics is the knowledge of the thermonuclear reactions responsible for powering the stellar engine and for the synthesis of the chemical elements. At astrophysical energies the cross section of nuclear processes is extremely reduced by the effect of the Coulomb barrier. The low value of cross sections prevents their measurement at stellar energies on Earth surface and often extrapolations are needed. The Laboratory for Underground Nuclear Astrophysics (LUNA) is placed under the Gran Sasso mountain and thanks to the cosmic-ray background reduction provided by its position can investigate cross sections at energies close to the Gamow peak in stellar scenarios. Many crucial reactions involved in hydrogen burning has been measured directly at astrophysical energies with both the LUNA-50kV and the LUNA-400kV accelerators, and this intense work will continue with the installation of a MV machine able to explore helium and carbon burnings. Based on this progress, currently there are efforts in several countries to construct new underground accelerators. In this talk, the typical techniques adopted in underground nuclear astrophysics will be described and the most relevant results achieved by LUNA will be reviewed. The exciting science that can be probed with the new facilities will be highlighted.

Search for second order response of nuclei to isospin probes and their connection to double beta decay

F. Cappuzzello[1]
1 Università degli studi di Catania, Italy

Abstract

In order to get quantitative information on neutrino absolute mass scale from the possible measurement of the $0\nu\beta\beta$ decay half-lives, the knowledge of the Nuclear Matrix Elements (NME) involved in such transitions is mandatory. Interesting studies were performed in the eighties, exploring (π^+, π^-) Double Charge Exchange (DCE) reactions on different nuclei with the main aim to unveil features of the nuclear response useful for $\beta\beta$-decay [1]. Unfortunately, such studies were abandoned quite soon, also due to the very different operators governing the two physical processes. One of the key concern was about the indirect excitation of the fundamental double spin-isospin Gamow-Teller modes by the spinless pions. Recently the use of heavy-ion induced double charge exchange (DCE) reactions as tools towards the determination of information on the NME has been proposed in Italy [2] and Japan [3]. The basic point is that there are a number of similarities between the two processes, mainly that the initial and final state wave functions are the same and the transition operators are similar, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components [4]. The NUMEN project at INFN-LNS laboratory in Italy proposes to explore the whole network of nuclear reactions connecting the initial and final nuclear states of the $\beta\beta$-decay. This includes DCE, Single Charge Exchange (SCE), multinucleon transfer reactions, elastic and inelastic scattering, with the purpose to fully characterize the properties of the nuclear wave functions entering in the $0\nu\beta\beta$ decay NMEs. Experimental campaigns are ongoing at INFN-LNS in order to explore medium-heavy ion induced reactions on target of interest for $0\nu\beta\beta$ decay. These studies are complemented by a strong activity on the theoretical side, especially tailored to give a detailed description of the challenging DCE reaction mechanisms [5]. An overview of recent activity performed in Catania in this field will be presented at the Conference.

[1] N. Auerback et al., Phys. Rev. Lett. 59, 1076 (1987)

[2] F.Cappuzzello et al., Eur. Phys. J. A 54: 72 (2018)

[3] M. Takaki et al., RIKEN Accelerator Progress Report 47 (2014)

[4] F.Cappuzzello et al., Eur. Phys. J. A 51: 145 (2015)

[5] H. Lenske et al., Prog. in Part. and Nucl. Phys. 109 103716 (2019)

Recent results on heavy-ion induced reactions of interest for neutrinoless double beta decay at INFN-LNS

M. Cavallaro[1]

1 Università degli studi di Catania, Italy

Abstract

Researches on neutrinoless double beta decay have crucial implications on particle physics, cosmology and fundamental physics. It is likely the most promising process to access the absolute neutrino mass scale. To determine quantitative information from the possible measurement of the $0\nu\beta\beta$ decay half-lives, the knowledge of the Nuclear Matrix Elements (NME) involved in such transitions is mandatory. The use heavy-ion induced double charge exchange (DCE) reactions as tools towards the determination of information on the NME is one of the goals of the NUMEN and the NURE projects. The basic point is that there are a number of similarities between the two processes, mainly that the initial and final state wave functions are the same and the transition operators are similar, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components. The availability of the MAGNEX magnetic spectrometer for high resolution measurements of the very suppressed DCE reaction channels is essential to obtain high resolution energy spectra and accurate cross sections at very forward angles including zero degree. The measurement of the competing multi-nucleon transfer processes allows to study their contribution and constrain the theoretical calculations. An experimental campaign is ongoing at INFN-Laboratori Nazionali del Sud (Italy) to explore medium-heavy ion induced reactions on target of interest for $0\nu\beta\beta$ decay. Recent results obtained by the (^{20}Ne,^{20}O) DCE reaction and competing channels, measured for the first time using a ^{20}Ne(10+) cyclotron beam at 15 AMeV will be presented at the conference. Preliminary results regarding the analysis of the double charge exchange channel in comparison with the competitive multi-nucleon transfer channels will also be shown and commented.

NDTGamma: Hadronic Parity Violation in Counting Mode

C. Crawford[1]
1 University of Kentucky, USA

Abstract
Recent hadronic parity violation results from the NPDGamma and n3He experiments have paved to path towards a complete mapping of the spin and isospin dependence of the Hadronic Weak Interaction, one of the poorest understood elements in the Standard Model. The remaining experimentally accessible observables in few-body systems pose special problems. For example, the statistical precision of the parity-odd neutron spin asymmetry of gammas in the reaction $\vec{\mathrm{n}} + \mathrm{d} \rightarrow \mathrm{t} + \gamma$, $A_{\gamma}^{\vec{n}d}$ from a practical target of D_2O would be diluted by the low signal-to-background ratio of the suppressed (mb) n-D capture cross section using conventional analog integration of current-mode signals. Given the moderate event rates from this reaction and modern capabilities of high-speed digital pulse-processing electronics, we describe the possibility of detecting and discriminating on individual gamma-rays from the 6.2 MeV photopeak. This would enable the first counting-mode measurement of Hadronic Parity Violation in a few-body system.

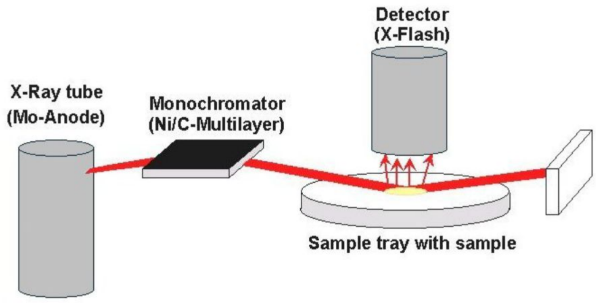
Total Reflectance X-ray Florescence Spectrometry for the analysis of Copper in Plants affected by Microscopic and Nanoscopic Carbon Allotropes

I.E. Serrato Mireles[1], J.A. Gómez Villa[1], J.L. Rodríguez Alejandre[1] and N. Dasgupta-Schubert[1]*
1 Universidad Michoacana, México
*nabanita.schubert@umich.mx

Abstract

X-Ray fluorescence (XRF) is an atomic excitation-deexcitation phenomenon that uniquely identifies the atomic number (Z) of the element emitting the fluorescent radiation through Moseley's law, which for the frequencies $\nu(K_\alpha)$ and $\nu(L_\alpha)$ of the K_α and L_α lines is, $\nu(K_\alpha) = (3/4)$ $(3.29\text{x}10^{15})$ (Z-1)2 Hz $\nu(L_\alpha) = (5/36)$ $(3.29\text{x}10^{15})$ (Z-7.4)2 Hz The equations demonstrate that spectral line resolution improves with Z. This has made it an attractive technique for the identification of super-heavy and exotic heavy nuclei [1]. Total Reflectance XRF (TXRF) spectrometry is a relatively recent advancement of the XRF technique [2]. The working principle of the S2-Picofox^{TM} (Bruker-GmbH) TXRF machine used in the current work is shown in the figure below. The key element is the grazing angle (0.3-0.6°) incidence of the exciting monochromatic beam which is $\leq$ the critical angle of the specularly reflective substrate, resulting in total reflection. The sample presented as a thin layer on the substrate, is excited by both the incident and the reflected beam. The emergent fluorescent beam is analysed by the detector-amplifier-multichannel analyser combine. The grazing incident and exit angles make possible a large solid-angle of collection at the detector, the reduction of substrate absorption and scattering as well as sample self-absorption. Consequently, higher sensitivities, the reduction of matrix effects and the avoidance of memory are achieved.

This work will discuss our recent results of the application of TXRF spectrometry to the analysis of Copper concentration profiles in the roots and shoots of Brassica juncea, a metal hyperaccumulating plant and the variation of these profiles when the plant is grown in soil spiked with a trace concentration (10 mg/kg) of two allotropes of Carbon whose dimensions occupy the two distinct scales of the micro and the nano.



[1] Proc. Int. Symp. Superheavy Elements, Lubbock, TX, USA (1978). https://doi.org/10.1016/C2013-0-03026-5

[2] R. van Grieken, A. Markowicz (Eds.). Handbook of X-Ray Spectrometry, Marcell-Dekker (2002)

Describing low-energy nuclear reactions with quantum wave-packet dynamics

A. Díaz-Torres[1]

1 University of Surrey, UK

Abstract

The physics of nuclear reactions is crucial for understanding element creation in the Universe, and is therefore at the core of science programmes in new generation nuclear research facilities. I will report on novel theoretical developments in describing low-energy fusion dynamics of heavy ions and weakly bound nuclei using the time-dependent wave-packet method [1]. Topical applications of the method include the incomplete fusion of weakly bound nuclei at Coulomb energies [2] and resonances in stellar carbon fusion [3]. Perspectives of the method for identifying resonant behaviour in nuclear collisions will be discussed [4].

[1] T. Vockerodt and A. Diaz-Torres, Physical Review C 100 (2019) 034606

[2] M. Boselli and A. Diaz-Torres, Physical Review C 92 (2015) 044610

[3] A. Diaz-Torres and M. Wiescher, Physical Review C 97 (2018) 055802

[4] A. Diaz-Torres and J.A. Tostevin, arXiv: 1809.10517

Neutrino Physics Opportunities at ORNL

A. Galindo-Uribarri[1]
1 Oak Ridge National Laboratory, USA

Abstract

The Physics Division at ORNL is exploring key opportunities for neutrino physics and supporting the formation of an experimental program at the intersection of particle, nuclear, and astrophysics. The Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR) of ORNL are two very powerful neutrino sources that open new physics opportunities. Two new experiments, PROSPECT and COHERENT, make use of these unique capabilities and enable us to broaden the understanding of neutrino properties. PROSPECT consists of segmented 6Li-loaded liquid scintillator antineutrino detectors designed to probe short-baseline neutrino oscillations and precisely measure the reactor antineutrino spectrum. The COHERENT collaboration aims to measure CEvNS (Coherent Elastic Neutrino-Nucleus Scattering) at the SNS. The CEvNS process is cleanly predicted in the Standard Model and its measurement provides a Standard Model test. I will present a novel neutrino experiment which consists of a differential measurement of coherent-elastic neutrino-nucleus scattering using isotopically enriched Ge detectors.

Study of semiconductor detectors using low energy ion accelerators

J. García López[1,2] and M.C. Jiménez Ramos[2]
1 University of Sevilla, Spain
2 CNA, Spain

Abstract

First we will briefly present the infrastructure available at the Centro Nacional de Aceleradores (CNA, Sevilla, Spain), based on a 3 MV tandem accelerator and a compact cyclotron, which are employed for Nuclear Physics experiments in multidisciplinary research, as the characterization and modification of materials using Ion Beams, the test of nuclear instrumentation, the irradiation of electronic devices and the production of neutrons beams. Then we will describe a methodology employed to evaluate the radiation hardness and the spectrometric properties of semiconductor detectors, using the Ion Beam Induced Current (IBIC) technique in a nuclear microprobe. The results are analysed through a theoretical approach based on the drift and diffusion of carriers in the active and neutral regions of the detector, and on the probability of electrons and holes recombination using the Shockley-Read-Hall model. Some illustrative examples of the IBIC technique will be shown, including the dose rate dependence on the generation of point defects in Si photodiodes after ion irradiation, the use of SiC detector as a plasma diagnostic system for the detection of alpha-born particles in ITER and the analysis of commercial thick Si(Li) detectors for charged particles.

Application of Trojan Horse Method to radioactive ion beams induced reactions

M. Gulino[1] **(for the ASFIN collaboration)**
1 Università degli studi di Enna-Kore, Italy

Abstract

The Trojan Horse Method is an indirect method useful to get information about the cross section of a reaction having two-body in the final state by means of an appropriate reaction with three-body in the final state. If the "indirect" reaction proceeds through a quasi-free mechanism, it is possible to factorize its cross section to infer information about the two-body reaction of interest. In the last decades, many experiments have demonstrated the validity of the method, and the method was extensively applied in the study of cross sections at very low energy of astrophysical interest, avoiding the suppression effects due to the presence of the Coulomb barrier. To be successfully carried out, the method requires a very accurate measurement of energy and angle of at least two of the three ejectiles, in order to reconstruct the whole kinematics and discriminate among different reaction mechanisms that can populate the same final state. Moreover, as the quasi-free events are a small fraction of the whole statistics (generally of the order of 10%, depending strongly on the reaction), it is mandatory to collect enough events to obtain reasonable statistical errors. These requirements hardly match with the typical low intensity and large divergence of radioactive ion beams, and only recently the possibility to extend the method to radioactive ion induced reactions has been investigated. Moreover, a very interesting application of this study is the possibility to measure cross section of neutron induced reactions on radioactive isotopes, even if they have a short lifetime. In the presentation the use of radioactive beams in Trojan Horse Method experiments will be discussed. In particular, some results obtained in the study of the reactions ^{18}F(p,α)^{15}O and ^{18}F(n,α)^{15}N will be presented.

Ab initio nuclear theory for beyond standard model physics

J. Holt[1]

1 TRIUMF, Canada

Abstract

Long considered a phenomenological field, breakthroughs in many-body methods together with our treatment of nuclear and electroweak forces are rapidly transforming modern nuclear theory into a true first-principles, or ab initio, discipline. In this talk I will discuss recent advances, which expand the scope of ab initio theory to global calculations of nuclei, including first predictions of the limits of nuclear existence into the medium-mass region, as well as pioneering new calculations of ^{208}Pb and nearby nuclei. I will then focus on recent extensions to fundamental problems in nuclear-weak physics, including a proposed solution of the long-standing gA quenching puzzle, calculations of neutrinoless double-beta decay for determining neutrino masses, and WIMP-nucleus scattering cross sections relevant for dark matter direct detection searches.

Quantum phase transitions within the semimicroscopic algebraic cluster model

D.S. Lohr-Robles[1], E. López-Moreno[2], P.O. Hess[1,3]
1 Instituto de Ciencias Nucleares, UNAM, México
2 Facultad de Ciencias, UNAM, México
3 Frankfurt Institute for Advanced Studies, Germany

Abstract

Quantum phase transitions (QPT), i.e. structural changes in a many body system, are studied within the framework of the semimicroscopic algebraic cluster model (SACM). Their properties are investigated using the methods of catastrophe theory for the study of a semi-classical potential obtained as the expectation value of the Hamiltonian in the basis of coherent states, and the parameter space of the model is constructed with the corresponding separatrices: the bifurcation set and the Maxwell set. The QPT manifests itself as qualitative changes of the potential as the parameters are varied across the separatrices. A novel procedure based on catastrophe theory is introduced to obtain the Maxwell set of a potential depending on parameters.

^{40}Mg and The Kerman Problem in the Continuum*

A.O. Macchiavelli [1]

1 Lawrence Berkeley National Laboratory, USA

Abstract

The effect of weak binding on nuclear structure, decay, and reactions is an open question in nuclear physics. On the neutron-rich side of stability, as the neutron separation energy approaches zero, weakly bound neutrons in the single-particle levels at the Fermi surface approach the edge of the nuclear potential and may move outside the core of well-bound nucleons, and possibly couple to unbound continuum states. The nature of this transition from a "closed" to an "open" quantum system [1], where binding is dominated by correlations rather than the mean field, has only just begun to be explored, and our understanding of weak-binding effects and coupling to the continuum is, in many ways, nascent. The first spectroscopic study of the near drip-line Nucleus ^{40}Mg [2], revealed two γ-ray transitions that suggest an excitation spectrum with unexpected properties as compared to both the systematics along the lighter Mg isotopes and available state-of-the-art theoretical model predictions. We will discuss a possible explanation for the observed structure in terms of weak-binding effects. In 1956 Kerman published a seminal paper on rotational perturbations in nuclei [3]. In the second part of the talk, we consider Kerman's problem when one of the single-particle levels involved is a resonant state. We will present some preliminary results showing the behavior of the moment of inertia and the decoupling parameter as a function of the state width.

*This material is based upon work supported by the U.S. DOE, Office of Science, Office of Nuclear Physics, under Contract No. DEAC0205CH11231.

[1] J. Dobaczewski, et al. Prog. Part. Nucl. Phys. 59, 432 (2007)

[2] H. L. Crawford, et al. Phys, Rev. Lett. 122, 052501 (2019)

[3] A. Kerman, Mat. Fys. Medd. Dan. Vid. Selsk., no. 15 (1956)

Weak nuclear processes in the quest for elusive particles

O. Moreno[1]
1 Universidad Complutense de Madrid, Spain

Abstract

Several nuclear processes involving the weak interaction have been proposed to extract information on some elusive features of particles or even on their very nature. One of these processes is parity-violating (PV) elastic electron scattering off nuclei, which can be used to determine accurately the density distribution of neutrons within the nucleus, and specifically the neutron skin thickness of heavy isotopes [1]; the latter can in turn be related to the size and structure of neutron stars. PV electron scattering can also be used to determine the content of strange quark-antiquark virtual pairs within the nucleon [2]. In addition to studying these elusive aspects of neutrons and strange quarks in nuclei, PV electron scattering can help in evaluating accurately Standard Model couplings, such as the weak-mixing angle, or higher-order radiative corrections. To achieve all these goals, low theoretical uncertainties are required in modeling some confounding nuclear effects, such as isospin mixing or Coulomb distortion of the electron wave function. We have estimated the sizes and uncertainties of such effects for a carbon 12 target [3]. Another elusive particle is the neutrino, whose coherent scattering by nuclei, mediated by the weak neutral interaction, has been measured only recently through the recoil of the nuclear target. We have computed coherent neutrino-nucleus cross sections and nuclear recoils for several targets, and have found a relationship between this process and electron-nucleus elastic scattering involving parity-violation [4]. Finally, nowadays the paradigm of evasive particle in physics is dark matter. Sterile neutrinos are hypothetical dark matter candidates that could be coherently scattered by nuclei through an indirect weak neutral interaction, or could be produced in nuclear beta decays leaving a signal in the energy spectrum of the emitted electron [5]. More generally, one can define dark matter candidates which interact with nuclei through a combination of vector and axial currents, analogous to the Standard Model weak neutral interaction but with different couplings. We have studied the direct detection rates of such hypothetical particles through axial and vector elas-

tic collisions with nuclei, as well as the corresponding nuclear recoils for a wide range of particle energies and masses and different nuclear targets [6].

[1] O. Moreno, P. Sarriguren, E. Moya de Guerra, J.M. Udias, T.W. Donnelly, and I. Sick, J. Phys.: Conf. Ser. 312, 092044 (2011)

[2] O. Moreno, T. W. Donnelly, R. González-Jimnez, and J.A. Caballero, J. Phys. G: Nucl. Part. Phys. 42, 034006 (2015)

[3] O. Moreno and T.W. Donnelly, Phys. Rev. C 89, 015501 (2014)

[4] O. Moreno and T.W. Donnelly, Phys. Rev. C 92, 055504 (2015)

[5] H.J. de Vega, O. Moreno, E. Moya de Guerra, M. Ramón Medrano, and N.G. Sánchez, Nucl. Phys. B 866, 177 (2013)

[6] O. Moreno, E. Moya de Guerra, and M. Ramón Medrano, Adv. High Ener. Phys. 2016, 6318102 (2016)

[7] O. Moreno and T.W. Donnelly, hep-ph/1603.05932v1

From Halo Effective Field Theory to the study of breakup and transfer reactions: reliably probing the halo structure of ^{11}Be and ^{15}C

L. Moschini[1], J. Yang[1,2] and P. Capel[1,3]

1 Université Libre de Bruxelles, Belgium
2 Afdeling Kern-en Stralingsfysica, Belgium
3 Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Germany

Abstract

In this work we study one-neutron halo nuclei. These exotic nuclei are found close to the neutron drip-line and exhibit a much larger matter radius than their isobars. This peculiar property is qualitatively understood as due to their low binding energy of one neutron, which then can tunnel far into the classically forbidden region and hence form like a diffuse halo around a compact core. Examples of these systems are ^{11}Be and ^{15}C, which can thus be seen as an inert core of ^{10}Be or ^{14}C plus a neutron. Due to their weakly-bound nature these systems are particularly unstable and hence their structure is studied mostly through indirect techniques, such as nuclear reactions. During the last decades several reactions involving these systems have been measured on different targets and different energies [1-5]. Our purpose is to study these different processes using one single structure model for each nucleus. So, we first find a description of the structure of ^{11}Be and ^{15}C within the Halo Effective Field Theory (Halo EFT) [6], extracting the main parameters to fit the core-neutron interaction from transfer reactions [7,8]; interestingly we find a good agreement with ab initio results for these nuclei [9,10]. Then, we study the breakup of these nuclei at intermediate (about 70A MeV) and high (at 520A and 605A MeV) energy using an eikonal model with a consistent treatment of nuclear and Coulomb interactions at all orders, which takes into account proper relativistic corrections [11]. We compare our results with measurements from RIKEN and GSI [1-4]. We find that our theoretical predictions are in good agreement with the experimental data for each reaction, thus assessing the robustness of the structure model provided for these nuclei. In particular, the use of Halo EFT allows to understand which elements of their structure matter in the description of nuclear reactions. We also show the importance of the inclusion of relativistic corrections in the case of the breakup at high energy.

[1] R. Palit et al., Phys. Rev. C 68, 054606 (2003)

[2] U. Datta Pramanik et al., Phys. Lett. B 551, 63-70 (2003)

[3] T. Nakamura et al., Phys. Rev. C 79, 035805 (2009)

[4] N. Fukuda et al., Phys. Rev. C 70, 054606 (2004)

[5] R. Reifarth et al., Phys. Rev. C 77, 015804 (2008)

[6] H.W. Hammer, C. Ji and D. R. Phillips, J. Phys. G 44, 103002 (2017)

[7] J. Yang and P. Capel, Phys. Rev. C 98, 054602 (2018)

[8] L. Moschini, J. Yang and P. Capel, Phys. Rev. C 100, 044615 (2019)

[9] A. Calci et al., Phys. Rev. Lett. 117, 242501 (2016)

[10] P. Navrátil, private communication

[11] L. Moschini and P. Capel, Phys. Lett. B 790, 367-371 (2019)

Unbound states in ^{16,18,20}C: the search for the mixed-symmetry 2^+ state

S. Murillo-Morales[1], M. Petri[1], and S. Paschalis[1] (for the R3B Collaboration)
1 University of York, UK

Abstract

We present the current status of the experimental investigation of the structure of unbound states of ^{16}C, ^{18}C and ^{20}C induced via quasi-free scattering $(\mathrm{p}, 2\mathrm{p})$ reactions from ^{17}N, ^{19}N, and ^{21}N, respectively. The experiment was carried out at the R3B-LAND setup at GSI-FAIR during the S393 campaign. We work upon the model of a two-state mixing of pure proton and pure neutron excitations to describe excited 2^+ states in neutron-rich carbon isotopes [1,2]. The first 2^+ state of ^{16}C has been measured [1] to be dominated by neutron excitations and recently confirmed in a study that has determined the proton amplitude of the first 2^+ state for ^{16}C, ^{18}C and ^{20}C [3]. We want to identify the mixed-symmetry 2^+ state, which is above the neutron separation energy and therefore unbound. Its observation will add weight to our simple picture of describing the neutron-rich C isotopic chain, giving us great insights into the shell evolution towards the neutron dripline at $Z = 6$.

[1] M. Petri et al., Phys. Rev. C. 86, 044329 (2012)

[2] A. O. Macchiavelli et al. Phys. Rev. C 90 067305 (2014)

[3] I. Syndikus. Technische Universitt Darmstadt. PhD thesis. *Proton-knockout reactions from neutron-rich N isotopes at R3B.*(2018)

Nuclear physics program with GRIFFIN at TRIUMF-ISAC-I

B. Olaizola[1] **(for the GRIFFIN collaboration)**
1 TRIUMF, Canada

Abstract

GRIFFIN (the Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei) is a state-of-the-art facility for decay spectroscopy with rare-isotope beams located at the TRIUMF-ISAC facility, Vancouver, Canada. At its core is an array of 16 HPGe clovers covering almost 4pi which, coupled with a custom-made, fully-digital DAQ, gives it one of the highest efficiency in the field. GRIFFIN can be coupled with a suit on ancillary detectors: SCEPTAR for beta tagging, PACES for electron conversion, LaBr for fast timing, DESCANT for neutron spectroscopy plus active BGO shields for all the gamma detectors. This versatility allows GRIFFIN to perform experiments using different spectroscopy techniques simultaneously, allowing an in-depth study of the nucleus in a single run that usually would require several simpler experiments. In this talk, I will present an overview of the GRIFFIN facility and its physics program, which encompasses three main pillar: nuclear structure, super-allowed beta decay and nuclear astrophysics. I will also discuss some of the latest physics results.

Neutron-Proton Pairing and its Impact on Gamow-Teller Transitions*

S. Pittel[1]

1 University of Delaware, USA

Abstract

In this talk I will discuss a systematic shell model study of Gamow-Teller (GT) transitions in the beginning of the 2p1f shell, with a schematic Hamiltonian that contains a quadrupole-quadrupole interaction as well as isoscalar (T=0) and isovector (T=1) pairing interactions. The use of the shell model enables us to analyze the role of the different proton-neutron pairing modes in the presence of nuclear deformation. We first obtain an optimal Hamiltonian that is able to acceptably reproduce the low-energy spectroscopic properties and the GT fragmentation properties of the nuclei of interest and then systematically vary the isoscalar and isovector pairing strengths to see how this impacts the distribution of GT transition intensities. The GT decays that we study are ^{42}Ca $\rightarrow$ ^{42}Sc, ^{44}Ca $\rightarrow$ ^{44}Sc, ^{46}Ti $\rightarrow$ ^{46}V and ^{48}Ti $\rightarrow$ ^{48}V. I will briefly summarize the key conclusions that emerged from the analysis.

*Work carried out in collaboration with Arturo Carranza and Jorge Hirsch.

Decay spectroscopy of heavy neutron-rich nuclei: towards the r-process path at N=126

Z. Podolyák[1]

1 University of Surrey, UK

Abstract

Information gained on neutron-rich N∼126 nuclei is essential for the understanding of nuclear structure in heavy nuclei. Studies around doubly magic systems allow direct tests of the purity of shell model wave functions. From a longer-term perspective, experiments in this region pave the way toward the proposed nuclear-astrophysical r-process waiting point nuclei along the N = 126 shell closure. Gamow-Teller β decay is forbidden if the number of nodes in the radial wave functions of the initial and final states is different. This Δn=0 requirement plays a major role in the β decay of heavy neutron-rich nuclei, affecting the nucleosynthesis through the increased half-lives of nuclei on the astrophysical r-process pathway below both Z=50 (for N>82) and Z=82 (for N>126). The level of forbiddenness of the Δn=1 ν1g9/2→π0g7/2 transition has been investigated [1] from the β-decay of the ground state of ^{207}Hg into the single-proton-hole nucleus ^{207}Tl in an experiment at the ISOLDE Decay Station. This is the most stringent test of the Δn=0 selection rule to date. In addition, a large number of excited states, several of them of octupole character were observed and compared with large scale shell model calculations. Systematic under-estimation of the octupole energy is noted. We suggest that in order to resolve the difference in predicted energies for collective and non-collective t=1 states (t is the number of nucleons breaking the ^{208}Pb core), the effect of t=2 mixing may be reduced for octupole-coupled states. The inclusion of mixing with t=0,2,3 excitations is necessary to accurately replicate all t=1 state energies [2]. The most exotic N∼126 nuclei studied so far were populated in fragmentation reactions at GSI (see e.g. [3,4]). Within the FAIR-0 experimental campaign a number of such studies will be performed within the DESPEC (Decay Spectroscopy) collaboration starting from spring 2020. The presentation will report on recent decay spectroscopy results and their relevance on the structure of neutron-rich nuclei around ^{208}Pb. Future plans will be also discussed.

[1] T. Berry et al., Phys. Lett. B 793, 271 (2019)

[2] T. Berry et al., to be published

[3] S. J. Steer et al., Phys. Rev. C 84, 044313 (2011)

[3] A. I. Morales et al., Phys. Rev. Lett. 113, 022702 (2014)

Neutron Skin Effects investigated by means of Mirror Energy Differences

A. Boso[1,2,3], **S.M. Lenzi**[1,2] **and F. Recchia**[1,2]
1 Università degli Studi di Padova, Italy
2 INFN, Sezione di Padova, Italy
3 National Physical Laboratory, UK

Abstract

INFN, Sezione di Padova, Padova, Italy and National Physical Laboratory, Teddington, Middlesex, United Kingdom **Abstract**

Energy differences between analogue states in the T=1/2 ^{23}Mg-^{23}Na mirror nuclei have been measured along the rotational yrast bands with the EXOGAM + Neutron Wall + DIAMANT setup at GANIL. The nuclei of interest have been populated via the ^{12}C+^{16}O fusion evaporation reaction. This allows us to search for effects arising from isospin-symmetry breaking interactions (ISB) and/or shape changes. Data are interpreted in the shell model framework following the method successfully applied to nuclei in the $f_{7/2}$ shell. It is shown that the introduction of a schematic ISB interaction of the same type of that used in the $f_{7/2}$ shell is needed to reproduce the data. An alternative novel description, applied here for the frst time, relies on the use of an effective interaction deduced from a realistic charge-dependent chiral nucleon-nucleon potential. This analysis provides two important results: (i) The mirror energy differences give direct insight into the nuclear skin; (ii) the skin changes along the rotational bands are strongly correlated with the diference between the neutron and proton occupations of the $s^{1/2}$ "halo" orbit.

Pushing the limits of analytical techniques for ultra-trace detection

E. Romero-Romero[1]

1 University of Tennessee, USA

2 Oak Ridge National Laboratory, USA

Abstract

The detection, monitoring and quantification of ultra-low levels of actinides is of considerable importance and represents a challenge in many fields of modern science: neutrino physics, dark matter searches, nuclear astrophysics, environmental science, etc. These fields are pushing the limits of conventional techniques for ultra-trace analysis, demanding more sensitive and more efficient techniques. I will report on two methods for ultra-trace analysis investigated: namely, the negative-ion based Accelerator Mass Spectrometry (AMS) and positive-ion based Resonant Ionization Mass Spectrometry (RIMS). Significant advances have been made on the ultra-trace detection of actinides. Overall efficiency of 51% for Pu, 32% for Th and 9% for U was obtained by resonant laser ionization using the best schemes observed in our study for each isotope. A detection limit of $6x10^3$ atoms using RIMS was obtained. A new value for the ionization potential of plutonium was established significantly more accurate than the NIST value.

Double charge exchange reactions and their relation with neutrinoless double beta decay

E. Santopinto[1], J. Ferretti, H. García-Tecocoatzi, R. Magana Vsevolodovna (for the NUMEN project)
1 INFN, Sezione di Genova, Italy

Abstract

The differential cross-section for Double Charge Exchange (DCE) has been very recently derived in the eikonal approximation and very forward angles [1]. Under those hypothesys we have shown for the first time that it is possible to factorize the DCE cross-section in terms of reaction and nuclear parts. Moreover,the explicit form for a double charge exchange effective potential has been derived in the closure approximation and also an explicit expression for the nuclear matrix elements, that are of the form of Double Gamow-Teller and Double Fermi [1]. Those matrix elements have been calculated in microscopic IBM-2 and we have shown, using the IBM formalism, a linear correlation between the Double Charge Exchange(DCE) Double Gamow Teller Nuclear Matrix Elements (NMEs) and the total parts of the neutrinoless double-beta decay NMEs. We discuss the possibility of placing an upper limit on neutrinoless double-beta decay NMEs in terms of the DCE experimental data.

[1] E. Santopinto, et al., Phys.Rev. C98 (2018) no.6, 061601

Fusion studies at around the barrier energies: A case $^{10}B+^{27}Al$

V.R. Sharma[1], E.F. Aguilera[1], J.C. Morales-Rivera[1], P. Amador-Valenzuela[1], E. Martínez-Quiroz[1], D. Lizcano[1]

1 Instituto Nacional de Investigaciones Nucleares, México

Abstract

Nuclear Reactions around the Coulomb barrier are complex in nature due to the existence of non-fusion channels at these energies, and offers excellent opportunities to explore several dynamical effects as well as the sub-lime effects of nuclear structure. Some of the outstanding issues related to nuclear reactions at these energies are: the role of nucleon transfer events in the manipulation of fusion cross-section, and pairing correlations. As such, a program has been undertaken to carry out some conclusive measurements for the $^{10}B+^{27}Al$ system at energies 1.2-1.7 MeV/A. The experiment based on gamma spectroscopy has been performed at the Instituto Nacional de Investigaciones Nucleares, México, to obtain the fusion cross-sections at several beam energies. Experimental details, analysis and preliminary results will be presented during the conference.

This work is partially supported by the CONACYT.

Interpretation of the LHCb Pc(4312) signal

J.A. Silva Castro[1]

1 Instituto de Ciencias Nucleares, UNAM, México

Abstract

We study the nature of the new signal reported by LHCb in the J/Ψ p spectrum. Based on the S-matrix principles, we perform a minimum-bias analysis of the underlying reaction amplitude, focusing on the analytic properties that can be related to the microscopic origin of the Pc(4312)+ peak. By exploring several amplitude parameterizations, we find evidence for the attractive efffor the attractive effect of the$\Sigma_c^+\overline{D^0}$ channel, that is not strong enough, however, to form a bound state.

Progress towards detection of atomic nuclear reaction products via optical imaging for Nuclear Astrophysics

J. Singh[1]

1 NSCL-Michigan State University, USA

Abstract

In this talk, I will discuss a proposed new method for measuring the cross section of low-yield nuclear reactions by capturing the products in a cryogenically frozen noble gas solid. Once embedded in the noble gas solid, which is optically transparent, the product atoms can be selectively identified by laser-induced fluorescence and individually counted via optical imaging to determine the cross section. Single-atom sensitivity by optical imaging is feasible because the surrounding lattice of noble gas atoms facilitates a large wavelength shift between the excitation and the emission spectrum of the product atoms. The tools and techniques from the fields of single-molecule spectroscopy and superresolution imaging in combination with an electromagnetic recoil separator, for beam and isotopic differentiation, allow for a detection scheme with near-unity efficiency, a high degree of selectivity, and single-atom sensitivity. This technique could be used to determine a number of astrophysically important nuclear reaction rates. I will describe the results of our first commissioning run of a prototype Single Atom Microscope (SAM) performed on the ReA3 beamline at the National Superconducting Cyclotron Laboratory in East Lansing, Michigan, USA.

[1] B. Loseth, R. Fang, D. Frisbie, K. Parzuchowski, C. Ugalde, J. Wenzl, and J. T. Singh Phys. Rev. C 99, 065805 (2019)

α-cluster states and their connection to the E1 strength of heavy nuclei

M. Spieker[1]
1 Florida State University, USA

Abstract

α-cluster states are well-established structural features of light to medium-mass nuclei, i.e. for nuclei up to about A = 40 [1,2]. Even though heavier nuclei are known to decay by α-particle emission, cluster states are far less accepted as a feature of their excitation spectrum. A few experimental studies are available, which provide some evidence for ^{208}Pb+α configurations in ^{212}Po, see, e.g., [3]. In the ^{154}Sm(d,^{6}Li)^{150}Nd α-transfer reaction, a possible rotational band built on an excited $J^{\pi}=0^{+}$ state was excited as strongly as the ground-state band [4]. Jänecke et al. [4] speculated whether the remarkable population could be explained by an α-cluster structure. In the rare-earth region, where Q_{α} values are generally small or even positive, a systematic, theoretical study performed in the framework of the interacting boson model showed that the experimental $B(E1;0^{+}\rightarrow 1^{-})$ strength distribution below 4 MeV could be explained if clustering was considered [5]. In the algebraic interpretation presented in [5] and references therein, the p boson was linked to α-cluster structures and the E1 decays attributed to the dynamic electric dipole moment induced by the charge-asymmetric cluster shape. If present in heavier nuclei, α-cluster states might be strongly populated in (α,γ)-capture and (γ,α)-photodisintegration reactions relevant in explosive stellar scenarios for the so-called p nuclides. 1^{-} and other low-spin, negative-parity states will be dominantly excited in photon-induced reactions via E1 transitions and will act as doorway states in the (γ,α) reaction if pre-clustered. In this contribution, I will present recent results on a possible α-cluster dipole mode, which were obtained in the framework of the spdf interacting boson model [5,6]. These extended studies of the low-lying E1 response support the general occurrence of α-cluster dipole states in atomic nuclei. Furthermore, I will briefly discuss a planned experimental program to study these states in α-transfer reactions with the Super-Enge Split-Pole Spectrograph at Florida State University.

[1] M. Freer, H. Horiuchi, Y. Kanada-En'yo, D. Lee, U.G. Meissner, Rev. Mod. Phys. 90, 035004 (2018)

[2] C. Beck, Ed., Clusters in Nuclei-Lecture Notes in Physics 818, Volume 1, Springer Verlag, Berlin Heidelberg, 2010

[3] A. Astier, P. Petkov, M.-G. Porquet, D. S. Delion, P. Schuck, Phys. Rev. Lett. 104, 042701 (2010)

[4] J. Jänecke, F. D. Becchetti, D. Overway, C. E. Thorn, Phys. Rev. C 26, 405 (1982).

[5] M. Spieker, S. Pascu, A. Zilges, and F. Iachello, Phys. Rev. Lett. 114, 192504 (2015)

[6] M. Spieker, S. Pascu, and A. Zilges, Journal of Physics: Conference Series 863, 012063 (2017)

Nuclear structure from electric monopole and magnetic moment measurements at the Heavy Ion Accelerator Facility

A. Stuchbery[1]
1 Australian National University, Australia

Abstract

This talk will review highlights of recent nuclear structure research at the Heavy Ion Accelera-tor Facility (HIAF) at the Australian National University. One of our over arching research themes concerns the emergence of collective structures in atomic nuclei from the underlying microscopic (shell) structure, including the question of whether nuclei really show two- and higher-phonon vibrations, and the role of shape coexistence. To contribute to this research theme, magnetic moment measurements have been made on the low-excitation states of the even isotopes $^{124-130}$Te. These measurements together with large basis shell model calculations give insights into the development of collectivity as successive pairs of neutron holes are removed from ^{132}Sn. The isotopes ^{120,122}Te show vibrational like energy patterns while the heaviest stable nuclide ^{130}Te is well described by shell model calculations with two protons and four neutron-holes outside ^{132}Sn. By measuring g fac-tors along with $B(E2)$ values we can track the competition between the effects of short-range residual interactions that give rise to pairing correlations, which tend to preserve the seniority structure, and longer-range residual interactions, which drive the quadrupole-collectivity that eventually emerges. Experimental electron spectroscopy of electric monopole ($E0$) transitions has recently focused on pair spectroscopy in lighter nuclei. These measurements include new measurements on the Hoyle state in ^{12}C, the first observations of the $0^+ \to 0^+$ decay in ^{24}Mg and the $E0$ decay from the superdeformed band in ^{40}Ca, as well as systematic studies of $E0$ transitions near $N = 28$. In other work, a time-dependent version of the recoil in vacuum method, based on Na-like ions, is being developed with the objective of giving accurate excited-state g factors for nuclei in the fp shell, and the more-conventional time-dependent perturbed angular distribution method is being combined with $LaBr_3$ detectors and hyperfine fields in ferromagnetic gadolinium hosts to make accessible g-factor measurements

on a range of shorter-lived isomers.

A scintillating bubble chamber for dark matter searches and coherent elastic neutrino-nucleus interactions

E. Vázquez Jáuregui[1]
1 Instituto de Física, UNAM, México

Abstract

Bubble chambers are nowadays used for rare event searches, such as galactic WIMP dark matter and neutrino interactions through coherent elastic nucleus scattering. SBC is a collaboration of 11 institutions from Canada, Mexico and USA with the goal to build and operate a 10kg scintillating liquid argon bubble chamber (SBC) to search for dark matter with masses between 0.7 and 7 GeV, as well as to measure reactor neutrinos through coherent elastic neutrino-nucleus interactions. The scintillating bubble chamber is an extension of the moderately-superheated bubble chamber technique pioneered by COUPP and now used by PICO to search for WIMP dark matter. This technique is expected to provide sensitivity to argon recoils with energies down to 100 eV, with excellent rejection of gamma, beta, and alpha backgrounds. A scale up of the proposed experiment would provide sensitivity in the targeted mass range down to the coherent scattering neutrino floor, a longstanding goal in the field. The current status of the construction and commissioning of the scintillating bubble chamber as well as its physics reach will be presented in this talk.

POSTER SESSION

Meson spectrum based on effective QCD model and their comparison with experimental data

G.A. Alcántara-Marín[1]

1 Instituto de Ciencias Nucleares, UNAM, México

Abstract

A low energy meson spectrum is derived from numerical calculation based on effective QCD model, it's described the influence of increasing total angular momentum in the energy levels density, the variation of the free parameters involves in the theory and the criteria to obtain a mean energy and width associated.The experimental spectrum is compared with the results obtained by applying the Random Phase Approximation at diagonalized hamiltonian.

Measurement of isotopic concentration of ^{14}C in an irradiated graphite control bar

D. Belmont, S. Sandoval-Hipólito, A.B. Zunun-Torres, A.O. Valdez-Guerrero, D.J. Marín-Lámbarri, A. Huerta, G. Reza, M.G. Rodríguez-Ceja, J. Mas-Ruiz, C. Solís and E. Chávez[1]

1 Instituto de Física, UNAM, México

Abstract

One of the most important advances for the humanity is the nuclear power, the efficiency is greater than other ways to produce electricity however, one of the most important disadvantages is the nuclear waste particularly the irradiated carbon from the control bars located in the core of the reactor. In this work we measure the isotopic concentration of ^{14}C of the bars used in the core for the very first-time using Accelerator Mass Spectrometry (AMS) technique, in Tandem-Type accelerator. Moreover, this fragment has been characterized trough gamma spectroscopy with hyper pure germanium detector. Our results show a high radioactive isotope concentration due to neutron capture reactions in the bar, this concentration is over six orders of magnitude higher in contrast with natural graphite. On the other hand, the gamma spectroscopy indicates radioactive isotopes agreeing with previous publications.

This work has been partially funded by CONACYT-UNAM 271802, 280760, 299073, 299186, 294537 and DGAPAUNAM IA103218 IG101016.

Authors are in debt to Sergio Martínez González for his help preparing the graphite cathodes.

Microscopic Space of the Nucleus ^{16}O

J.R.M. Berriel-Aguayo[1]
1 Instituto de Ciencias Nucleares, UNAM, México

Abstract
The space of the nucleus ^{16}O is compared to space with the SACM against the space of Kato. The differences between the spaces is discussed and in the construction of energies, the missing and excess states do not affect the energies in an important way.

Study of the $^{12}C(^{12}C,p)$ and $^{12}C(^{12}C,\alpha)$ nuclear reactions below the coulomb barrier

L.E. Charon[1], L. Acosta[1], L. Barrón-Palos[1], D. Belmont[1], E.Chávez[1], K.P. Gaitán de los Ríos[1], D. Godos-Valencia[1], A. Huerta[1], D.J. Marín-Lámbarri[1], J. Mas-Ruiz[1], C.G. Méndez-García[1], F.F. Morales-González[1], G. Reza[1], S. Sandoval-Hipólito[1], C. Solís[1] and T. Zanatta-Martínez[1]

1 Instituto de Física, UNAM, México

Abstract

Nuclear fusion reactions between ^{12}C nuclei are among the most important in the evolution of star systems. In neutron stars it can lead to a supernova explosion. At thermonuclear energies ECM = 1.5 MeV, the reactions $^{12}C+^{12}C$ take place through the channels alpha and p. To understand these events it is necessary to know its cross section between 1 and 3 MeV of energy(center of mass), interval of interest in Astrophysics. Since these energies are much smaller than the height of the Coulomb barrier (ECM=6.1 MeV) the measurements are a challenge due to the extremely small values of the cross sections. The cross section of this system$^{12}C+^{12}C$ has been measured only at a minimum energy of 2.10 MeV (at the center of mass). These measured cross sections have big uncertainties in the range of energies of interest in Nuclear Astrophysics and there are discrepancies between their results which is why, nowadays, great efforts are being made to improve the accuracy of these measurements. In this poster I will describe the ongoing effort at the National Laboratory of Accelerator Mass Spectrometry (LEMA by its name in Spanish) of the National Autonomous University of Mexico to measure this cross section at energies between 3 and 2 MeV in the center of mass.

This work has been partially funded by PIIF-2018 "Estudio de Reacciones Nucleares a Bajas Energías Utilizando Núcleos de $^{12,13,14}C$" and PAPIIT IN111913, IG101016 "Astrofísica Nuclear". Authors want to acknowledge Mr. Sergio Martínez Gonzáles for his help during the sample preparation at LEMA.

Semimicroscopic Algebraic Cluster Model (SACM): ^{32}S and the concept of forbiddenness

L.J. Chávez-Nuñez[1]
1 Instituto de Ciencias Nucleares, UNAM, México

Abstract

The SACM is applied to the system ^{16}O+^{16}O $\rightarrow$ ^{32}S , in order to build a microscopic space which satisfies the Pauli's Exclusion Principle (PEP). Therefore, it has been required to include the concept of forbiddenness. Experimental spectra has been well reproduced, the same as the transition values. Forbiddennes is used in a two-cluster system and its importance for ^{32}S is shown, and the low energy states could be reproduced for the first time for such system. Results are compared with experiments and previews works.

Mechanical coupling of the supersonic gas jet target SUGAR to the AGATA+NEDA systems for the measurement of stable beams reactions at LNL

C. Flores-Vázquez[1], L. Acosta[2], D.J. Marín-Lámbarri[2], E. Chávez[2], L. Barrón-Palos[2], A. Huerta[2], F. Favela[3], J. Valiente-Dobón[4], D. Mengoni[5,6], A. Gottardo[4], I. Lombardo[7], D. Dell'Aquila[8], A.M. Sánchez-Benítez[9] and T. Kurtukian-Nieto[10].

1 Facultad de Ingeniería, UNAM, México
2 Instituto de Física, UNAM, México
3 Instituto de Ciencias Nucleares, UNAM, México
4 Laboratori Nazionali di Legnaro, Istituto Nazionale di Fisica Nucleare, Italy
5 Università degli Studi di Padova, Italy
6 Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy
7 Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Italy
8 National Superconducting Cyclotron Laboratory (NSCL), Michigan State University
9 Universidad de Huelva, Spain
10 Centre D'Etudes Nucélaires de Bordeaux-Gradignan, France

Abstract

SUGAR, acronym of "SUpersonic Gas jet tARget", is a recent array developed at Instituto de Física, Universidad Nacional Autnoma de México (IF-UNAM). It was commissioned at the end of 2015. SUGAR is a windowless gas target, so a beam can be fully exploited without lousing energy resolution, taking besides advantage of the gas target purity compared with solid targets. The original idea to create a supersonic target comes from the necessity to continue using low energy stable beams, where there are still many reactions of interest, particularly those related with astrophysical problems. As part of an international collaboration between IFUNAM and Istituto Nazionale di Fisica Nucleare, Italy, SUGAR is been proposed to be coupled to AGATA and NEDA arrays, to perform a set of new experiments, once AGATA will back to Laboratori Nazionali di Legnaro. The components of SUGAR were replicated through CAD software, in order to create a mechanical design free to be modified and assembled with AGATA and NEDA components. This free model was coupled with AGATA+NEDA models, establishing the starting point for the necessary modifications of the system to reach a realistic setup, including the three arrays. In the present work, the main characteristics of new SUGAR models and the coupling with AGATA+NEDA arrays, as well as to the LNL-beam line, are described in detail.

This work is partially supported by the projects: DGAPA-PAPIIT IA103218 and IN107820.

Characterization of MgO/carbon targets for ^{26}Al production by proton irradiation

D. Godos-Valencia[1], C.G. Méndez-García[1,2], L. Acosta[1]
1 Instituto de Física, UNAM, México
2 Cátedra CONACyT, IFUNAM, México

Abstract

The radioisotope ^{26}Al is very interesting nuclei for Nuclear Astrophysics. Although it has a large enough half-life (106 years) to be produced in a star and then spread out to the interstellar media, its production sources in the galaxy are not well determined yet. Consequently, knowing more about the cross-sections for its production, makes possible to identify its sources and abundancies, doing possible to access new information for cosmological models. One of the most important natural ways to produce ^{26}Al, is by means of the ^{25}Mg(p,γ)^{26}Al reaction. In order to approach the study of such reaction, AMS + reaction production may be used. This means to create the radioisotope by proton irradiation on Mg target and later to measure ^{26}Al nuclei produced, by using AMS technique. The present work is associated to Mg thin layers deposition on carbon substrates (glassy-carbon), in order to create ideal targets to be later irradiated with proton beams. The main characteristics of the Mg deposition and the microscopic analysis of the final structure of the targets, using Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM), are here described.

Efficency of a HPGe extended range detector for determination of ^{7}Be concentration in air filters

O.E. López[1]

1 Centro de Investigacin en Materiales Avanzados, Chihuahua, México

Abstract

Using the GEANT4 Monte Carlo simulation software, the efficiency of the HPGe extended range detector of the Environmental Radiological Surveillance Laboratory of CIMAV was modeled. A ^{137}Cs certified point source was employed to determine the experimental efficiency in the desired geometry for the energy of 662 keV. The resulting value was compared with the theoretical efficiency obtained by the Monte Carlo simulation. The results of the simulation were consistent with the experimental one. The same method was applied to calculate the theoretical efficiency in the same detector for borosilicate filters in an extended geometry. The energy then was 477 keV, of the gamma quanta from ^{7}Be, to determine its concentration in air. This efficiency value was applied for air sampling in the city of Chihuahua.

Fusion cross sections for the ^{9}Be+^{51}V system measured around the Coulomb barrier*

E. Martínez-Quiroz[1], P. Amador-Valenzuela[1], J.C. Morales-Rivera[1], E.F. Aguilera[1] and D. Lizcano[1]

1 Instituto Nacional de Investigaciones Nucleares, México

Abstract

Recently, the fusion cross sections were measured for the ^{9}Be+^{51}V system, around the Coulomb barrier, using the EN Tandem Van de Graaff Accelerator facility at ININ. The bombardments were performed for projectile energies from 9.0 MeV to 18.0 MeV range in steps of 0.5 MeV. The comparison of experimental results with predictions of fusion- evaporation code, e.g. PACE2 indicates that in some cases the residual nuclei, like ^{52}V, are produced much more than predictions. In the case of ^{52}V, this nucleus can be produced via 2-α evaporation channel and/or via 1n transfer channel. The theoretical analysis is still in progress to try to elucidate which of these two channels is more relevant in the production of ^{52}V.

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Hadronic Nuclear Radius

J. Mas-Ruiz[1], L. Acosta[1], A. Huerta[1], E. Chávez[1], J.P. Fernández-García[2]

1 Instituto de Física, UNAM, México
2 Universidad de Sevilla, Spain

Abstract

This work is a progress report of the study of the hadronic nuclear radius through the measurement of elastic and transfer reactions at low energies of different projectile-target combinations. Calculations of angular distributions between 90° and 180° are compared with published data below 7 MeV. Computer codes "FRESCO" and "NRV" were used with the "São Paulo" and "Woods-Saxon" potentials. Results are presented. Future work includes measurement of elastic and transfer reaction angular distributions of protons, deuterons and alphas on isotopic ^{9}Be, ^{12}C, ^{27}Al, ^{28}Si targets.

This work has been partially funded by CONACYT-UNAM 271802, 280760, 299073, 299186, 294537 and DGAPAUNAM IA103218 IG101016.

First characterization of the SIMAS array: the K-Mean algorithm modification proposed to optimize the calibration on 20+130 micron telescopes

F.F. Morales-González[1], L. Acosta[1], C. Flores-Vázquez[2], E. Chávez[1], D.J. Marín-Lámbarri[1] and A.M. Sánchez-Benítez[3]
1 Instituto de Física, UNAM, México
Facultad de Ingeniería, UNAM, México
Universidad de Huelva, Spain

Abstract

In this work, the preliminary results achieved for the calibration of telescopes from "SIMAS" detection array, a high segmentation mobile system dedicated to low-energy reaction studies, are presented. The non-uniformity of thin 20 micron detectors is faced by using a triple-alpha source, searching to establish a reliable calibration method of a whole telescope taking advantage of the DSSSD pixilation. The use of basic Machine Learning algorithms is proposed for the study of the data of the whole array, starting with a single telescope.

This work is partially supported by the projects: DGAPA-PAPIIT IA103218 and IN107820.

^{6}Li on ^{27}Al: A study focused to the elastic scattering

J.C. Morales-Rivera[1], E.F. Aguilera[1], E. Martínez-Quiroz[1], P. Amador-Valenzuela[1], V.R. Sharma[1]
1 Instituto Nacional de Investigaciones Nucleares, México

Abstract
Studies on the elastic scattering of stable and radioactive beams on different targets have been of great interest to the scientific community to understand the nuclear structure, as well as the processes involved in the evolution of the universe. For this reason, recently, the elastic scattering of ^{6}Li on ^{27}Al was measured in the Tandem Van de Graaff Accelerator facility, of the National Institute of Nuclear Research, México. Angular distributions and reaction cross sections for beam energies between 7.5 and 10 MeV were obtained. The results were complemented with Optical Model calculations, in particular a variant of the São Paulo Potential.

Work supported by CONACyT, México.

Electromagnetic Couplings of Heavy Baryons and Pentaquarks

E. Ortiz-Pacheco[1], R. Bijker[1], A. Giachino[2] and E. Santopinto[2]
1 Instituto de Ciencias Nucleares, UNAM, México
2 Genova

Abstract
In this work, we present an extension of the usual three to four flavors quark model (u, d, s and c (or b)) and we make a classification of heavy baryon states. Moreover, we develop a study of radiative decays of heavy baryons in the deformed quark model, in which we distinguish between the masses of light (q) and heavy (Q) quarks, within baryon configurations qqQ and QQq. The treatment is for both the S and P wave states. In particular, we focus on the two decays $\Sigma_Q^{*+}(uuQ) \to \Sigma_Q(uuQ) + \gamma$ and $\Lambda_Q^*(udQ) \to \Lambda_Q(udQ) + \gamma$, the generalization to the rest of baryon decays is obtained immediately considering flavor symmetry.

Design of a spin flipper for epithermal neutrons to study P violation in compound nuclei resonances

A. Pérez-Martín[1] **and L. Barrón-Palos**[1]

1 Instituto de Física, UNAM, México

Abstract

An adiabatic spin flipper was designed as a part of a neutron transmission experiment developed at LANSCE (Los Alamos Neutron Science Center) in order to study parity violation. Specifically the aim is to measure the parity-odd transmission asymmetry of longitudinally polarized neutrons through targets containing nuclei with p-wave neutron-nucleus resonances. The parity violating terms are highly dependent on the spin orientation, the magnetic field and the target polarization, so the spin has to be precisely manipulated. The shape of the ideal magnetic field for the spin flipper was found, then an arrangement of electric currents was designed to produce such a field. The efficiency of the spin flipper and its dependence on the magnetic field intensity was calculated. According to the calculations the electric current value was selected to generate a magnetic field resulting in high and stable efficiency. In the future, using a similar experimental setup, the same nuclei, and a variation of the spin flipper, time reversal invariance violation will be studied at J-PARC (Japan).

The 5.5 MV CN-Van de Graaff accelerator upgraded-ion source

C.G. Puigbert-Angulo[1], **R. Espejel**[1], **R. Gleason**[1], **D.J. Marín-Lámbarri**[1], **C. Valencia**[1] **and E. Chávez.**[1]

1 Instituto de Física, UNAM, México

Abstract

The 5.5 MV CN-Van de Graaff (VDG) accelerator (HVECO) was first installed in the early 50s at the Rice University (Houston, TX). It was donated to the “Institute of Physics”, U.N.A.M. in 1984 and started a new life in 1988. Its radio-frequency positive-ion source is composed of a number of voltage and current sources that power the electric and magnetic fields required to create the positive-ions, confine and transport them into the accelerator's tube. At the end of 2017, the ion source was severely damaged, several power supplies were destroyed. In this work we describe the process of restoring the VDG terminal, in which we correct the detected faults and change many components of the sources for more modern ones. Specifically, the modified sources were the “probe voltage”, the “source magnet”, the “extraction voltage” and the RF oscillator. All had old components, for example, Germanium diodes or grinding bulbs that are difficult to acquire today and do not have the same efficiency as the components available in the current market. As a result of the work carried out during most of 2019, the VDG accelerator is now operational and the experiments are being scheduled for 2020.

This work has been partially funded by CONACYT-UNAM 271802, 280760, 299073, 299186, 294537 and DGAPAUNAM IA103218 IG101016.

Z' and Higgs boson production associated with a top quark pair $t\bar{t}$, as a probe of the $\mathbf{U(1)}_{B-L}$ model at $\mathbf{e^+e^-}$ colliders ILC and CLIC

F. Ramírez Sánchez[1]

1Universidad Autńoma de Zacatecas, México

Abstract

We study the production sensitivity of the light and heavy Higgs bosons h and H, in relation with the possible existence of Z' boson and a top quark pair at the energy scales that will be reached in the near future at projected e^+e^- linear colliders. Our analysis is developed within the frame of an extension $U(1)_{B-L}$ of the Standard Model (SM). We focus in the resonance and no-resonance effects of the annihilation processes $e^+e^-\to(Z,Z')\to t\bar{t}h$ and $e^+e^-\to(Z,Z')\to t\bar{t}H$. Furthermore, we develop and present novel analytical formulae to assess the total cross-section involved in the production of Higgs bosons. We find that the possibility of performing precision measurements for the Higgs bosons h, H and for the Z' boson is very promising at future e^+e^- linear colliders.

Setup and installation of an extended range Bonner type spectrometer assembly in Mexico's Nuclear Center

A. Varela[1], **R. Policroniades**[1]. **E. Moreno**[1], **M.A. Sánchez González**[1,2]
1 Instituto Nacional de Investigaciones Nucleares, México
1 Universidad Autónoma del Estado de México, México

Abstract

The installation of a normal and extended range (spherical and cylindrical) Bonner type spectrometer assembly at ININ's Nuclear Center is supported as a continuation of the measurements of the neutron spectra, originated by cosmic radiation impinging on the earths atmosphere, which were taken at the IFUNAM' slocation in México City a few years ago. Nowadays, we are collecting (daily) data with a set of eight normal and extended range detector devices, at the Tandem Accelerator Laboratory facility of ININ, sited 2950 m above sea level at Ocoyoacac, México.

Development and installation of a Chopper prototype in the ININ's TRIGA Mark III reactor

A. Varela[1], R. Policroniades[1], G. Murillo[1], E. Moreno[1], M.A. Sánchez González[1,2], R. Raya[1], S. Cruz[1]

1 Instituto Nacional de Investigaciones Nucleares, México
2 Universidad Autónoma del Estado de México, México

Abstract

In order to provide the TRIGA Mark-III reactor with additional infrastructure, that could allow the implementation of nuclear applications, essential for the development of the country, a Fermi type electromechanical Chopper has been designed, built and mounted on the horizontal thermal column of the reactor, which permits the measurement of the energy spectrum of neutrons from the thermal column and its applications. A MCS time of flight spectroscopy (TOF) method was used, a method that records the time it takes for a neutron to travel a certain known distance, then associating it with the kinetic energy of the neutron.

Characterization of molecular beams of Carbon at high energies

S. Sandoval-Hipólito[1], D. Belmont[1], A. Huerta[1], D.J. Marín-Lámbarri[1], G. Reza[1], J. Mas-Ruiz[1], M.G. Rodríguez-Ceja[1], C. Solís[1] and E. Chávez[1]

1 Instituto de Física, UNAM, México

Abstract

The key of the success of the Accelerator Mass Spectrometry (AMS) technique, in Tandem-Type accelerators, is the claim that all possible molecular contamination is eliminated as they are destroyed in the charge exchange canal (striper). In this work we inject at 235 keV kinetic energy C-16 molecules into the charge exchange canal (Argon) of our Tandem Accelerator and measure the survival fraction of C2,3,4 in charge states +1 and +2. Our results show that some molecules remain bound, with one or more electrons missing, after being forced through a low-density gas at relatively high energy. Authors are indebted to Sergio Martínez Gonzáles for his help preparing the graphite cathodes.

This work has been partially funded by CONACYT-UNAM 271802, 280760, 299073, 299186, 294537 and DGAPAUNAM IA103218 IG101016.

Charged particle transport into an E, B and ExB fields

V.R. Sharma[1], E.F. Aguilera[1], P. Amador-Valenzuela1, J. Ramírez Jimenez[2], J.C. Morales-Rivera[1], E. Martínez Quiroz[1]

1 Instituto Nacional de Investigaciones Nucleares, México

Abstract

For low energy nuclear reaction cross-section measurements, an electrostatic deflector in combination with a time of flight telescope is the best choice. In such systems, a passage of a single ion through a thin secondary emission foil generates electrons that are transported to the detecting system by applying suitable electric, magnetic or crossed electric and magnetic fields. As a matter of fact, the fundamental nature of motion of a charged particle is captured in the Lorentz equation which defines the trajectory of charged particles in response to electric and magnetic fields. To understand and to determine the compact design of a spectrometer, Monte Carlo simulations of electron transport have been performed using GEANT4 computational tool. Simulations that describe the electron transport and the achievable detection system position will be presented during the conference. This work is partially supported by the CONACYT.

First proton beams of the reconstructed ion source of the Van de Graaff 5.5 MV Accelerator.

A.O. Valdez-Guerrero[1], E. Andrade[1], D. Belmont[1], R. Espejel[1], R. Gleason[1], D.J. Marín-Lámbarri[1], J. Mas-Ruiz[1], C.G. Puigbert[1], G. Reza[1], S. Sandoval-Hipólito[1], A.B. Zunun-Torres[1] and E. Chávez[1]

1 Instituto de Física, UNAM, México

Abstract

Low energy accelerators are of great importance today in several fields, such as Nuclear Astrophysics or elementary material analysis. The 5.5 MV Van de Graaff accelerator, commissioned at IFUNAM in 1988, has been instrumental characterizing materials with the help of various Ion Beam Analysis techniques. As of this year and through great teamwork, the ion source has been rebuilt, resulting in a new era in the investigation of ion interaction with matter in the institute. This work shows the first RBS spectra with proton beams of energies from 745 to 1200 keV generated by the accelerator on a natCu target.

This work has been partially funded by CONACYT-UNAM 271802, 280760, 299073, 299186, 294537 and DGAPAUNAM IA103218 IG101016. Authors acknowledge Carlos Valencia for his technical support.

Development of an electromagnetic device for polarization by MEOP and spin transport of ^{3}He used as a comagnetometer in the pursuit of the neutron electric dipole moment

T. Zanatta[1] and L. Barrón-Palos[1]

1 Instituto de Física, UNAM, México

Abstract

Multiple theories have been developed with the main objective of explaining fundamental physical phenomena whose nature remains unknown for humanity. It is believed that behind this enigma certain phenomena that violate the discrete symmetries of physics could be hidden, that is why the search focuses on the phenomena that results from assuming such violations, in particular CP symmetry. One of the main predictions that comes from assuming this hypothesis is the existence of the neutron electric dipole moment and this is the one property that the collaboration nEDM@SNS (neutron Electric Dipole Moment at Spallation Neutron Source) is searching for, aiming to improve the precision of the current measurements, whose current upper limit is $3\text{x}10^{-26}$ e·cm. The goal to achieve is a limit of the order of $d_n \sim 10^{-28}$ e·cm. We present the design of an electromagnetic device that will become a part of the experimental system at PULSTAR reactor in North Carolina State University, where operational and systematic studies are carried out in order to improve the mentioned experiment. This device aims to maintain the ^{3}He polarization via MEOP (Metastability Exchange Optical Pumping) so it can be used as a co-magnetometer. The device consists of an empty cylinder coil with circular covers on the top and bottom and which provides an uniform 5 G magnetic field inside, with defined magnetic field gradients according to relaxation times of polarization. We present the final design of the device and the optimal volumes with high magnetic field uniformity inside them, suitable enough to introduce the polarization MEOP system in the coil for two different relaxation times and hence two gradient restrictions.

Study of the reaction ^{28}Si(d,α)^{26}Al

A.B. Zunun-Torres[1], G. Reza[1], L. Acosta[1], P. Amador[2], L. Barrón-Palos[1], D. Belmont[1], L.E. Charón[1], A. Huerta[1], D.J. Marín-Lámbarri[1], J. Mas-Ruiz[1], C.G. Méndez-García[1], E. Moreno[2], G. Murillo[2], S. Padilla[1], R. Policroniades[2], S. Sandoval-Hipólito[1], C. Solís[1], A. Varela[2], P. Villaseor[2] and E. Chávez[1]

1 Instituto de Física, UNAM, México
2 Instituto Nacional de Investigaciones Nucleares, México

Abstract

Production of ^{26}Al is important in number of stellar scenarios for the nucleosynthesis of the heavy elements. For that reason in previous years we did measurements of the ^{28}Si(d,α)^{26}Al reaction at low energies. In this work, we continued with this study expanding the bombarding energy interval and, most importantly, taking advantage of the recently acquired expertise in the radiochemistry process to separate Aluminum from Silicon. Concentrations of ^{26}Al on the bombarded targets were measured by AMS in LEMA.

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